Dr. Schübeler, of Christiania, on "The Effect of Uninterrupted Sunlight on Plants in the Arctic Regions." These observations fully confirm the conclusion indicated by my experiments with electric light. Not only are plants able to grow continuously, according to Dr. Schübeler, but when under the influence of continuous light they develop more brilliant flowers and larger and more aromatic fruit than under the alternating influence of light and darkness, whereas the formation of sugar appears to be dependent chiefly upon temperature.

It would follow from these observations, that with the aid of stoves and electric light, fruit, excelling both in sweetness and aroma, and flowers of great brightness, may be grown without solar aid. Dr. Schübeler mentions that in removing an Acacia plant from the dark, and placing it under the influence of the arctic midnight sun, the leaves opened slowly, and it is interesting to observe that the same effect took place when an *Acacia lophantha* was placed (in the open air) under the influence of my midnight lamp.

March 11, 1880.

THE PRESIDENT in the Chair.

The Presents received were laid on the table, and thanks ordered for them.

The following Papers were read:—

I. THE CROONIAN LECTURE.—"On some Elementary Principles in Animal Mechanics. No. IX. The Relation between the Maximum Work done, the Time of Lifting, and the Weights Lifted by the Arms." By the Rev. SAMUEL HAUGHTON, M.D. (Dubl.), D.C.L. (Oxon.), F.R.S., Fellow of Trinity College, Dublin. Received February 28, 1880.

In the preceding note (No. VIII) I have shown that, in lifting weights at a fixed rate with the arms, until fatigue sets in, the following equation, deduced from the law of fatigue, is complied with, very closely:—

$$\frac{n(1+\beta^2t^2)}{t}=A \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

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where n=number of lifts,

t=time of each lift,

$\left.\begin{array}{l}\beta\\ A\end{array}\right\}$ coefficients to be found from the experiments themselves.

From this equation, and from the experiments themselves, it appeared that there was a particular time of lift—

$$t=\tau,$$

at which the maximum work was done, and that,

$$\tau=\frac{1}{\beta} \quad \ldots\ldots\ldots\ldots \quad (2).$$

The object of the series of experiments carried on during six months of the winter of 1876–7, and described in the present note, was to find in what manner the co-efficients τ, or β, vary with the weight employed and lifted. The experiments were conducted in every respect as those described in Note VII, the conditions of which I here quote and repeat:—

" The following experiments were made during the last six months upon Dr. Macalister:—

" A pair of dumbbells, held one in each hand, were raised simultaneously, from the vertical to the horizontal position, and again lowered, at a rate regulated by a metronome made for the purpose. No rest was allowed at the beginning or end of the motion, which took place as before, under the following conditions, viz.:—

" 1. To keep time with the metronome.

" 2. To raise the weights in the transverse plane.

" 3. To supinate the hands.

" 4. To abstain from all bending of the knees or spinal column.

" 5. The experimenter not to count the lifts.

" The experiments were made at intervals of never less than 24 hours, so as to avoid all risk of the muscles becoming trained; and on each occasion the weights were lifted until it became impossible to effect another lift, without violating condition No. 4, indicating that other muscles were called in to aid the shoulder muscles already worn out."

I have embodied in this note, the experiments made upon Dr. Macalister in 1875–6, Note VIII, " Proc. Roy. Soc.," vol. xxv, p. 132.

I.

w=9·75 lbs. (1875–6.)

No.	t.	n.
1	0·50 sec.	19·0
2	0·66 ,,	24·6
3	1·00 ,,	26·2
4	1·50 ,,	23·6
5	2·00 ,,	20·0
6	3·00 ,,	14·2
7	4·00 ,,	12·4
8	6·00 ,,	8·5

From these experiments I found A=50·7, β=1·00, τ=1·00 sec.

II.

w=7·75 lbs. (October, 1876.)

t. sec.	n.	t. sec.	n.	t. sec.	n.	t. sec.	n.	t. sec.	n.
0·50 ..	22	0·66 ..	42	0·75 ..	41	1·0 ..	40	2·0 ..	27
,, ..	25	,,	40	,,	48	,, ..	37	,,	33
,, ..	23	,,	44	,,	50	,, ..	38	,,	31
,, ..	26	,,	42	,,	47	,, ..	40	,,	33
,, ..	26	,,	38	,,	49	,, ..	36	,,	33
Mean ..	24·4		41·2		47·0		38·2		31·4

In discussing these experiments, it will be found that the first must be rejected, as its results differ from all the others. The rate of work was too fast, and the experiment was stopped by respiratory distress rather than by muscular fatigue.

The other four sets of experiments, when treated as in No. VIII, give the following results :—

β.	$\frac{\delta A}{\Sigma A}$.
1·25	4·59 per cent.
1·29	4·33 ,,
1·30	4·26 ,,
1·31	4·30 ,,
1·33	4·53 ,,
1·40	5·13 ,,

Hence we obtain the constants

A=113·75, β=1·30, τ=0·77 sec.

III.

w=5·87 lbs. (December, 1876.)

t.	*n.*	*t.*	*n.*	*t.*	*n.*
0·50 sec.	60	0·66 sec.	69	1·00 sec.	57
,, ...	59	,, ...	71	,, ...	57
,, ...	55	,, ...	78	,, ...	57
,, ...	61	,, ...	71	,, ...	64
,, ...	57	,, ...	70	,, ...	60
Mean....	58·4		71·8		59·0

Discussing these experiments as before, we obtain :—

β.	$\frac{\delta A}{\Sigma(A)}$.
1·50	5·74 per cent.
1·45	5·30 ,,
1·41	5·10 ,,
1·40	5·03 ,,
1·39	5·02 ,,
1·38	5·16 ,,
1·35	5·43 ,,
1·30	5·92 ,,
1·25	6·44 ,,
1·20	6·94 ,,

Hence we obtain the constants

$$A=182{\cdot}2, \qquad \beta=1{\cdot}395, \qquad \tau=0{\cdot}716 \text{ sec.}$$

IV.

w=2·62 lbs. (January, 1877.)

t.	*n.*	*t.*	*n.*	*t.*	*n.*
0·50 sec.....	140	0·55 sec.	260	0·66 sec.	209
,, ...	160	,, ...	424	,, ...	215
,, ...	204	,, ...	528	,, ...	225
,, ...	174	,, ...	762	,, ...	260
,, ...	208	,, ...	827	,, ...	227
,, ...	234	,, ...	382	,, ...	216
,, ...	227	,, ...	382	,, ...	268
,, ...	455	,, ...	467	,, ...	569
,, ...	411	,, ...	1072	,, ...	393
,, ...	507	,, ...	411	,, ...	254
Mean	271·8		551·5		283·6

It will be observed that, with light weights, the experiments vary much more than with heavy weights. The discussion of these experiments shows a less satisfactory agreement with equation (1) than the other experiments with heavier weights. The most probable values of the constants are as follows:—

β.	$\frac{\delta A}{\Sigma(A)}$.
1·0	26·5 per cent.
1·1	26·1 ,,
1·2	25·7 ,,
1·3	25·4 ,,
1·4	25·0 ,,
1·5	24·8 ,,
1·6	24·8 ,,
1·7	24·9 ,,
1·8	25·0 ,,
1·9	25·1 ,,
2·0	25·2 ,,

Hence we find

$$A=1128, \qquad \beta=1{\cdot}55, \qquad \tau=0{\cdot}645.$$

Bringing all the results into one table, we have

No.	w.	A.	β.	τ.
1	9·75 lbs.	50·7	1·000	1·000
2	7·75 ,,	113·7	1·300	0·770
3	5·87 ,,	182·2	1·395	0·716
4	2·62 ,,	1128·0	1·550	0·645

From all these experiments, it appears that the central cubic (1) derived from the law of fatigue, represents fairly the relation between n and t; and that n reaches a maximum for a time of lift τ, which varies with the weight, increasing with it, but not proportionally.

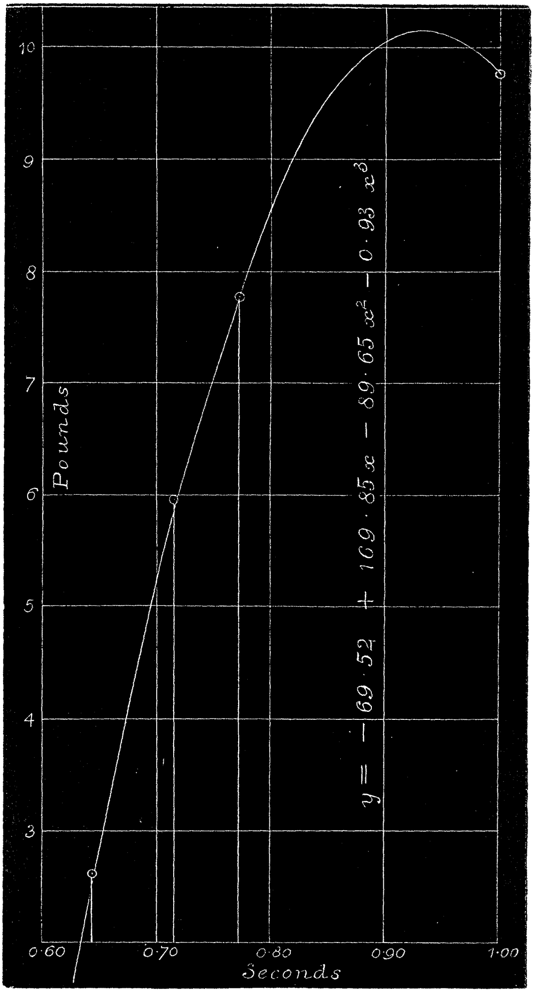
The time of lift corresponding to the maximum work done with each weight, ranges from 0·645 sec. to 1 sec. Within these limits (in order to interpolate) let us assume:—

$$w=a+b\tau+c\tau^2+d\tau^3 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3).$$

Introducing the four results from the table just given, we find:—

$$\begin{aligned} a&=-\ \ 69{\cdot}52, \\ b&=+169{\cdot}85, \\ c&=-\ \ 89{\cdot}65, \\ d&=-\ \ \ \ 0{\cdot}93, \end{aligned}$$

from which the curve (3) can be plotted.

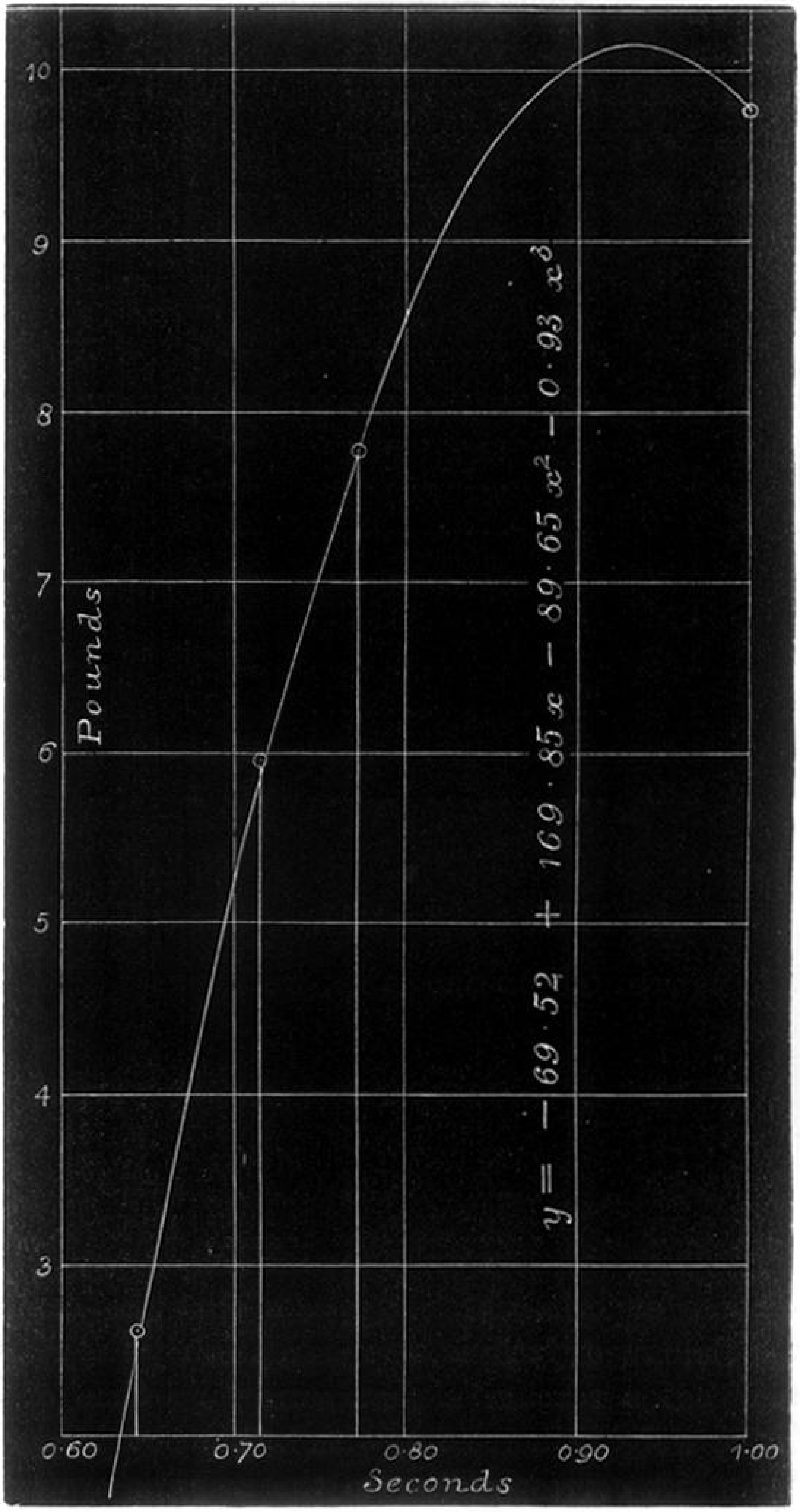


This curve is shown in the figure, and represents the relation between w and τ within the limits. The ordinate w reaches a maximum, within these limits when—

$$\frac{dw}{d\tau}=0,$$

which gives us

$$w=10\cdot17 \text{ lbs.}$$
$$\tau=0\cdot932 \text{ second.}$$


10
9
8
7
6
5
4
3
Pounds
$y = -69 \cdot 52 + 169 \cdot 85\,x - 89 \cdot 65\,x^2 - 0 \cdot 93\,x^3$
0·60
0·70
0·80
0·90
1·00
Seconds